APPENDIX E - TIMBER FASTENERS

CONNECTOR DESIGN VALUES

DESIGN OF MULTIPLE BOLT CONNECTIONS

BOLT DESIGN VALUES

P = ALLOWABLE LOAD PARALLEL TO GRAIN IN POUNDS
Q = ALLOWABLE LOAD PERPENDICULAR TO GRAIN IN POUNDS

MEMBER SIZE	1/2" BOLT		5/8" BOLT		3/4" BOLT		7/8" BOLT		1" BOLT	
	P	Q	P	Q	P	Q	P	Q	P	Q
1.5	940	430	1180	490	1420	540	1660	600	1890	650
2.0	1170	570	1550	650	1880	720	2210	790	2520	870
2.5	1260	860	1820	810	2310	900	2740	990	3150	1080
3.0	1270	980	1960	970	2630	1080	3220	1190	3750	1300
3.5	1270	1010	1980	1130	2800	1260	3580	1390	4270	1520
4.0	1270	1010	1990	1290	2850	1440	3790	1590	4670	1730
4.5	1270	1010	1990	1400	2860	1620	3880	1790	4930	1950
5.0	1270	1010	1990	1410	2860	1750	3890	1990	5000	2170
5.5	1270	1010	1990	1410	2860	1880	3900	2180	5070	2380
6.0	1270	1010	1990	1380	2860	1860	3900	2240	5070	2540
6.5	1270	1010	1990	1340	2860	1850	3900	2300	5070	2700
7.0	1270	1010	1990	1300	2860	1830	3900	2360	5070	2870
7.5	1270	1010	1990	1260	2860	1820	3900	2420	5080	3030
8.0	1270	1010	1990	1260	2860	1780	3900	2380	5080	3010
8.5	1270	1010	1990	1260	2860	1730	3900	2340	5080	2990
9.0	1270	1010	1990	1260	2860	1690	3900	2300	5080	2980
9.5	1270	1010	1990	1260	2860	1640	3890	2270	5080	2960
10.0	1270	1010	1990	1260	2860	1640	3890	2270	5080	2910
10.5	1270	1010	1990	1260	2860	1640	3890	2270	5080	2860
11.0	1270	1010	1990	1260	2860	1640	3890	2270	5080	2810
11.5	1270	1010	1990	1260	2860	1640	3900	2060	5080	2770
12.0	1270	1010	1990	1260	2860	1640	3900	2060	5080	2710

TABLE E-1

LAG SCREWS WITHDRAWAL AND LATERAL LOAD DESIGN VALUES

DOUGLAS FIR-LARCH [a]

LENGTH OF LAG SCREW IN MAIN MEMBER (in)	DIAMETER OF LAG SCREW (in)	WITH-DRAWAL VALUE[b] (lb/in)	LATERAL LOAD VALUES[c] (lbs.)			
			1.5" Side Member		2.5" Side Member	
			P[d]	Q[e]	P[d]	Q[e]
4	1/4	232	170	170		
	5/16	274	220	180		
	3/8	314	250	190		
	7/16	353	280	190		
	1/2	390	290	190		
	5/8	461	360	210		
5	1/4	232	200	200		
	5/16	274	290	250		
	3/8	314	380	290		
	7/16	353	420	290		
	1/2	390	440	280		
	5/8	461	530	320		
6	1/4	232	230	220		
	5/16	274	330	280		
	3/8	314	420	320	380	290
	7/16	353	520	360	440	310
	1/2	390	600	390	470	310
	5/8	461	710	430	550	330
	3/4	528			630	350
	7/8	593			720	370
	1	656			800	400

(a) Species Group II, specific gravity 0.51. Values for other species available by contacting the Sacramento Office of Structure Construction.

(b) Design values of withdrawal in pounds/inch of-penetration of threaded part into side grain of member holding point,

(c) Lateral load per lag screw in single shear.

(d) Parallel to grain.

(e) Perpendicular to grain.

TABLE E-2

CONNECTOR DESIGN VALUES

LAG SCREWS **WITHDRAWAL AND LATERAL LOAD DESIGN VALUES**

DOUGLAS FIR-LARCH [a]

LENGTH OF LAG SCREW IN MAIN MEMBER (in)	DIAMETER OF LAG SCREW (in)	WITH-DRAWAL VALUE[b] (lbs/in)	LATERAL LOAD VALUES[c] (lbs.)			
			1.5" Side Member		2.5" Side Member	
			P[d]	Q[e]	P[d]	Q[e]
7	1/4	232	240	230		
	5/16	274	350	300		
	3/8	314	460	350	430	330
	7/16	353	560	390	580	410
	1/2	390	660	430	650	420
	5/8	461	780	470	750	450
	3/4	528			850	470
	7/8	593			970	500
	1	656			1090	540
8	3/8	314			480	370
	7/16	353			630	440
	1/2	390			770	500
	5/8	461			970	580
	3/4	528			1090	600
	7/8	593			1220	630
	1	656			1370	690
9	3/8	314			520	400
	7/16	353			680	480
	1/2	390			830	540
	5/8	461			1130	680
	3/4	528			1350	740
	7/8	593			1470	760
	1	656			1660	830

See TABLE E-2 for footnotes.

TABLE E-3

COMMON NAIL WITHDRAWAL AND LATERAL LOAD DESIGN VALUES

DOUGLAS FIR-LARCH[a]

NAIL PROPERTIES Penny Weight	6d	8d	10d	12d	16d	20d	30d	40d
Length (inches)	2	2.5	3	3.25	3.5	4	4.5	5
Diameter[b] (inches)	.113	.131	.148	.148	.162	.192	.207	.225
WITHDRAWAL[c]								
Withdrawal Value (lbs/inch)	29	34	38	38	42	49	53	58
LATERAL[d]								
Desired Penetration (inches) 11 diameters	1.24	1.44	1.63	1.63	1.78	2.11	2.28	2.48
Lateral Value at Desired Penetration (lbs)	63	78	94	94	108	139	155	176
Minimum Penetration (inches)	.41	.48	.54	.54	.59	.70	.76	.83
Lateral Value at Minimum Penetration (lbs)	21	26	31.1	31.1	36	46.1	51.7	58.7

(a) Species Group II, specific gravity 0.51. Values for other species available by contacting the Sacramento Office of Structure Construction.

(b) Diameters apply to nails before application of any protective coating.

(c) Design values of withdrawal in pounds/inch of penetration into side grain of member holding point.

(d) Design value for lateral loads (single shear).

TABLE E-4

BOX NAIL **WITHDRAWAL AND LATERAL LOAD DESIGN VALUES**

DOUGLAS FIR-LARCH[a]

NAIL PROPERTIES Penny Weight		6d	8d	10d	12d	16d	20d	30d	40d
Length	(inches)	2	2.5	3	3.25	3.5	4	4.5	5
Diameter[b]	(inches)	.099	.113	.128	.128	.135	.148	.148	.162
WITHDRAWAL[c]									
Withdrawal Value (lbs/inch)		25	29	33	33	35	38	38	42
LATERAL[d]									
Desired Penetration (inches) 11 diameters		1.09	1.24	1.41	1.41	1.49	1.63	1.63	1.78
Lateral Value at Desired Penetration (lbs)		51	63	76	76	82	94	94	108
Minimum Penetration (inches)		.36	.41	.47	.47	.50	.54	.54	.59
Lateral Value at Minimum Penetration (lbs)		17	21	25.3	25.3	24	31.3	31.7	36

(a) Species Group II, specific gravity 0.51. Values for other species available by contacting the Sacramento Office of Structure Construction.

(b) Diameters apply to nails before application of any protective coating.

(c) Design values of withdrawal in pounds/inch of penetration into side grain of member holding point.

(d) Design value for lateral loads (single shear).

TABLE E-5

DOUBLE HEAD SCAFFOLD NAIL WITHDRAWAL AND LATERAL LOAD DESIGN VALUES

DOUGLAS FIR-LARCH[a]

NAIL PROPERTIES Penny Weight		6d	8d	10d	16d	20d	30d
Length[b]	(inches)	1.75	2.25	2.688	3.125	3.625	4.063
Diameter[c]	(inches)	.113	.131	.148	.162	.192	.207
WITHDRAWAL[d]							
Withdrawal Value	(lbs/inch)	29	34	38	42	49	53
LATERAL[e]							
Desired Penetration (inches) 11 diameters		1.24	1.44	1.63	1.78	2.11	2.28
Lateral Value at Desired Penetration (lbs)		63	78	94	108	139	155
Minimum Penetration (inches)		.41	.48	.54	.59	.70	.76
Lateral Value at Minimum Penetration (lbs)		21	26	31.1	36	46.1	51.7

(a) Species Group II, specific gravity 0.51. Values for other species available by contacting the Sacramento Office of Structure Construction.

(b) Length tip to top of lower head. This is the length to be used when duplex nails are used. Overall length of nail is same as that of a common nail.

(c) Diameters apply to nails before application of any protective coating.

(d) Design values of withdrawal in pounds/inch of penetration into side grain of member holding point.

(e) Design value for lateral loads (single shear).

TABLE E-6

SPIKE WITHDRAWAL AND LATERAL LOAD DESIGN VALUES

DOUGLAS FIR-LARCH[a]

NAIL PROPERTIES Penny Weight	10d	12d	16d	20d	30d	40d	50d	60d
Length (inches)	3	3.25	3.5	4	4.5	5	5.5	6
Diameter[b] (inches)	.192	.192	.207	.225	.244	.263	.283	.283
WITHDRAWAL[c]								
Withdrawal Value (lbs/inch)	49	49	53	58	63	67	73	73
LATERAL[d]								
Desired Penetration (inches) 11 diameters	2.11	2.11	2.28	2.48	2.68	2.89	3.11	3.11
Lateral Value (lbs) at Desired Penetration	139	139	155	176	199	223	248	248
Minimum Penetration (inches)	.70	.70	.76	.83	.89	.96	1.04	1.04
Lateral Value (lbs) at Minimum Penetration	46.1	46.1	51.7	58.9	66.1	74.1	82.9	82.9

(a) Species Group II, specific gravity 0.51. Values for other species available by contacting the Sacramento Office of Structure Construction.

(b) Diameters apply to nails before application of any protective coating.

(c) Design values of withdrawal in pounds/inch of penetration into side grain of member holding point.

(d) Design value for lateral loads (single shear).

TABLE E-7

MULTIPLE FASTENERS

WOOD SIDE PLATE (REDUCTION) FACTORS FOR LATERALLY LOADED CONNECTORS (BOLTS OR LAG-SCREWS)

A	B	NUMBER OF FASTENERS IN A ROW							
A_1/A_2	A_1 (in^2) [a]	2	3	4	5	6	7	8	9
0.0 [b][c]	< 12	1.00	0.87	0.76	0.67	0.58	0.51	0.45	0.39
	12 - < 19	1.00	0.92	0.82	0.75	0.66	0.58	0.52	0.48
	19 - < 28	1.00	0.94	0.89	0.83	0.75	0.69	0.62	0.58
	28 - < 40	1.00	0.96	0.93	0.88	0.82	0.77	0.72	0.67
	40 - < 64	1.00	1.00	0.94	0.91	0.86	0.81	0.78	0.73
	> 64	1.00	1.00	0.96	0.91	0.86	0.83	0.79	0.76
1.0 [b][c]	< 12	1.00	0.97	0.92	0.85	0.78	0.71	0.65	0.59
	12 - < 19	1.00	0.98	0.94	0.89	0.84	0.78	0.72	0.66
	19 - < 28	1.00	1.00	0.97	0.93	0.89	0.85	0.80	0.76
	28 - < 40	1.00	1.00	0.99	0.96	0.92	0.89	0.86	0.83
	40 - < 64	1.00	1.00	1.00	0.97	0.94	0.91	0.88	0.85
	> 64	1.00	1.00	1.00	0.99	0.96	0.93	0.91	0.88

Notes: 1. A_1 = cross-sectional area of main member.
2. A_2 = cross-sectional area of side member(s).

(a) When A_1/A_2 exceeds 1.0, use A_2 instead of A_1.
(b) When A_1/A_2 exceeds 1.0, use A_2/A_1 instead.
(c) For A_1/A_2 between 0 and 1.0, interpolate from the tabulated values.

TABLE E-8

DESIGN OF MULTIPLE-FASTENER CONNECTIONS [1]

Section 1 General Information

1.01 Introduction

The procedure for evaluating the adequacy of connections made with bolts and lag screws, as discussed in Section 4-3, Timber Fasteners, applies only to connections made with one fastener or two fasteners installed in a line parallel to the side member. In a two-fastener connection where the fasteners are not installed in a line parallel to the side member, or in any connection where more than two fasteners are used, the design procedures are modified in accordance with industry design criteria for multiple-fastener connections.

Industry requirements for multiple-fastener connections that are applicable to falsework construction, and the procedures necessary to accommodate them, are explained in the following sections.

1.02 Definitions

1.02A Row of Fasteners

A row of fasteners aligned with 'the direction of the applied load consists of the following:

- Two or more bolts of the same diameter loaded in single shear or double shear.
- Two or more lag screws of the same type and size loaded in single shear.

1.02B Group of Fasteners

A group of fasteners consists of one or more parallel rows of the same type of fastener arranged symmetrically with respect to the axis of the load.

1.02C Width of Fastener Group

The overall width of a fastener group is defined as the center-to-center spacing of the adjacent rows, except as provided in the following paragraph.

---

[1] The design criteria and procedures discussed herein apply to both bolt and lag screw connections. In the text, the term "fasteners" includes bolts and lag screws. For simplicity, in some cases the term "bolts" is used alone; however, such use is understood to include lag screws as well.

When the fasteners in adjacent rows are staggered and the distance between the adjacent rows is less than one-fourth of the distance between the closest fasteners in the adjacent rows, the adjacent rows are considered to be a single row when determining the design value for the. fastener group.

When only one row of fasteners is used, or when adjacent rows are considered to be a single row as provided in the preceding paragraph, the width of the fastener group for design purposes will be the minimum parallel-to-grain spacing of the fasteners.

1.02D L/D Ratio

L/D is the ratio of the length, L, of the fastener in the main member to its diameter, D.

1.03 Spacing and Clearance Requirements

1.03A Spacing Along a Row

Fastener spacing is measured between the centers of adjacent bolts or lag screws.

For parallel-to-grain loading when the actual bolt load equals the allowable design load, the minimum spacing between bolts in a row parallel to the grain is 4 times the bolt diameter. If the actual bolt load is less than the allowable load but not less than 75 percent of the allowable load, the spacing may be reduced proportionately, but not below 3 bolt diameters regardless of the actual bolt load. [2]

For perpendicular-to-grain loading, spacing between bolts or lag screws in a row perpendicular to the grain is limited by the spacing requirements of the attached member or members loaded parallel to the grain.

1.03B Spacing Between Rows

Spacing between adjacent rows is measured between the row centerlines.

For parallel-to-grain loading, the minimum spacing across the grain between rows of bolts is l-1/2 bolt diameters. [2]

For perpendicular-to-grain loading, as with brace to post connections, the spacing parallel to the grain between rows of

[2] When lag screws are used, the minimum spacings are the same as required for bolts of a diameter equal to the shank diameter of the lag screw used.

bolts must be at least 2-l/2 bolt diameters for L/D ratios of 2. or less and 5 bolt diameters for L/D ratios of 6 or more. For ratios between 2 and 6, the minimum spacing may be obtained by straight-line interpolation.

The maximum spacing between adjacent rows of fasteners may not exceed 5 inches, regardless of other considerations.

1.03C Edge and End Distance Requirements

Except as provided in the following paragraph, edge and end distance requirements for multi-fastener connections are the same as the requirements for single fastener connections.[3]

For parallel-to-grain loading in tension or compression, the minimum edge distance is 1-l/2 bolt (or lag screw) diameters, except that when the L/D ratio is more than 6, the minimum edge distance is l-1/2 diameters or one-half the distance between adjacent rows, whichever is greater.

1.04 Fastener Placement for Loads at an Angle to Grain

When the load is applied at an angle to the grain, as is the case with falsework bracing, industry practice requires that the gravity axis of all members in the connection must pass through the center of resistance of the fastener group.

l-05 Cross-Sectional Areas

The procedure for evaluating the adequacy of multiple-fastener connections uses reduction factors that are a function of an equivalent cross-sectional area based on the width of the fastener group in each of the members making up the connection.

For bolted connections, the equivalent cross-sectional area is the product of the width of the fastener group (as defined herein in Section 1.02, Definitions) and the thickness of the member under consideration. When lag screws are used, the thickness of the main member is the depth of penetration of the lag screw into the main member.

When a member is loaded in the perpendicular to the grain direction, as a falsework post loaded by the bracing, its equivalent cross-sectional area is the product of the thickness of the member and the overall width of the fastener group under consideration.

For the calculations, gross cross-sectional areas are used with no reduction for bolt or lag screw holes.

---

[3]See Chapter 4, Section 4-3, Timber Fasteners.

1.06 Connector Design Values

(a) The design value for a group of fasteners is the sum of the design values for the individual rows in the group.

(b) The design value for a row of fasteners of the same size and type cannot exceed the value of P_r as given by the following formula:

$$P_r = KP_s$$

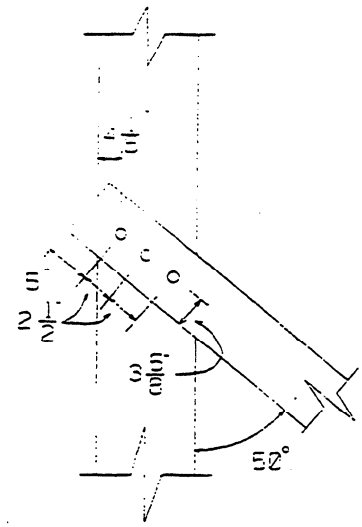
where P_r = the resultant design value, in pounds, for the row of fasteners.

P_s = the summation of the design values for the individual fasteners in a row.

K = the modification (reduction) factor for the number of fasteners in a row. Modification factors are shown in Table E-8.

Section 2 Example Calculations

Example 1



Given:

12 x 12 post with single 2 x 8 brace.

3 - 5/8" bolts in a single row.

Center of gravity of the bolt group coincides with the center of gravity of the members.

Determine the allowable load on the group of fasteners.

Spacing of bolts in a row

4D = (4)(0.625) = 2.5 inches minimum (used)

End distance

Use the more critical value for tension since the brace could be in either tension or compression.

7D = (7)(0.625) = 4.375 inches minimum < 5"

Edge distance

For the main member:

4D = (4)(0.625) = 2.5 inches minimum < 4.125"

For the side member:

1.5D = (l-5)(0.625) = 0.938 inches < 1.25"

Determine the single bolt value

Side member value = (O.75)(1960) = 1470 lbs.

Main member value using the modified Hankinson's formula:

$$\frac{(0.75)(1990)(1260)}{(1990)(\sin^2 50) + (1260)(\cos^2 50)} = 1114 \text{ lbs.}$$

The value for the main member controls.

Example 1 (Continued)

Determine the capacity of the bolt group

$$P_{GROUP} = K(\text{no. of fasteners})(\text{single bolt value})$$

$$= K(3x1114)$$

$$= K(3342) \text{ lbs/row}$$

The value for reduction factor K is obtained from Table E-8, after calculating the cross-sectional area of the side and main members. (See Table E-8.)

A_1(main member) = (2.5) (12) = 30.00 in^2

A_2 (side member) = (1.5) (2.5) = 3.75 in^2

$A_1/A_2 = 30.00/3.75 = 8.00$

Since $A_1/A_2 > 1$, use the value of A_2/A_1 when entering Column A and use the value of A_2 when entering Column B.

$A_2/A_1 = 3.75/30.00 = 0.125$

For Table E-8, Column A values are: 0.0 < 0.125 < 1.0; Column B value is: < 12; and the K value is found by interpolation:

Column A	Column B	Column for 3 fasteners
0.0	<l2	0.87
0.125	<l2	K
1.0	<12	0.97

Solve for K:

$$\frac{(0.125 - 0.0)}{(1.0 - 0.0)} = \frac{(K - 0.87)}{(0.97 - 0.87)}$$

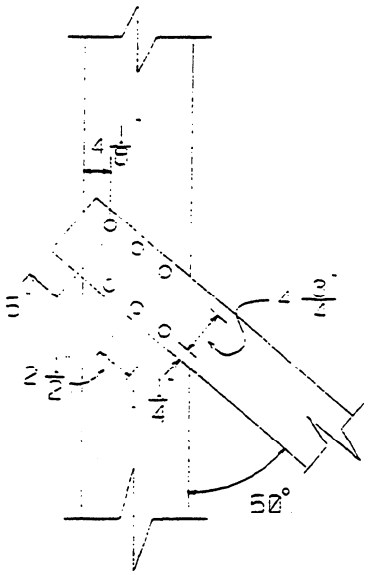
$$\frac{0.125}{1.0} = \frac{(K - 0.87)}{0.10}$$

$$0.0125 = K - 0.87$$

$$K = 0.883$$

and $P_r = K(P_{GROUP}) = (0.883 \times 3342) = 2951$ lbs.

Example 2



Given:

12 x 12 post with a 2 x 8 brace on each side.

6- 5/8" bolts arranged in two rows of 3 connectors each.

Center of gravity of the bolt group coincides. with the center of gravity of the members.

Determine the allowable load on the group of fasteners.

1. For the side member (loading parallel to grain):

Spacing of bolts in a row

4D = (4)(.625) = 2.5 inches minimum

Spacing between rows of bolts

1.5D = (l.5)(.625) = .938 inches minimum

End distance

Use the value for tension since brace could be either in tension or compression..

7D = (7)(.625) = 4.375 inches minimum

Edge distance

1.5D = (1.5) (.625) = .938 inches

Number of rows of fasteners

Distance between adjacent rows = 4.75", which is greater than 2.5/4 = 0.625. Therefore, analyze as 2 rows of bolts.

Example 2 (Continued)

2 . For the main member (loading perpendicular to grain):

Spacing between rows

L/D = 12/(0.625) = 19.2

5D = (5)(.625) = 3.125 inches minimum < 4.75"

Edge distance

Use 4D since load reversal is possible.

4D = (4) (.625) = 2.50 inches minimum < 4.125"

Determine single bolt value

Side member value = (0.75)(1960) = 1470 Lbs.

Main member value using modified Hankinson's formula:

$$\frac{(0.75)(1990)(1260)}{(1990)(\sin^2 50) + (1260)(\cos^2 50)} = 1114 \text{ LBS}$$

The value for the main member controls.

Determine the capacity of the bolt group

P_{GROUP} = K(No. of fasteners) (single bolt value)

= K(3)(1114)

= K(3342) LBS/row

Reduction factor K is obtained from Table E-8. To enter Table E-8 it is necessary to calculate the cross-sectional -area of the side and main members.

A_1 (main member) = (4.75)(12) = 57.00 in^2

A_2 (side member) = (1.5)(4.75) = 7.125 in^2

A_1/A_2 57.00/7.125 = 8.00

Example 2 (Continued)

Since A_1/A_2 > 1, use the value of A_2/A_1 when entering Column A and use the value of **A,** when entering column B. (See Table E-8.)

A_2/A_1 7.125/57.00 = 0.125

For Table E-8, Column A values are: 0.0 < 0.125 < 1.0; Column B value is: < 12; and the K value is found by interpolation:

Column A	Column B	Column for 3 fasteners
0.0	<l2	0.87
0.125	<l2	K
1.0	<l2	0.97

By interpolation, K = 0.883

and $P_r = K(P_{GROUP})$

= [(0.883)(3342 lbs/row](2 rows) = 5902 lbs.